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Processo de desenho do projeto demonstrativo de baixo impacto ambiental: Centro de Interpretacion Cañadón del Duraznillo, Patagonia Argentina

Design process of the environment low-impact demonstrative project: Interpretation Center Cañadón del Duraznillo, Argentine Patagonia

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Abstract

This paper presents the design process of the Cañadón del Duraznillo Interpretation Center, located in the San Jorge Gulf in the Argentine Patagonia. This project was commissioned as a result of the creation of the Cañadón del Duraznillo Nature Reserve on the Atlantic coast of the Province of Santa Cruz, Argentina with the aim of preserving the biodiversity of the sea-coastal environment associated with the Patagonian Steppe. The Interpretation Center program includes a multi-use space meant for exhibitions, conferences and film projections; an administrative office, a house for a park ranger and a room for guest researchers. From the first morphological sketches to the selection of materials and working details, this design process was guided by simulations and studies of the environmental conditions specific to this particular case, as well as by guidelines and general recommendations appropriate for this climate and geographical location gathered from previous design experience and specialized literature. The studies performed included simulations of direct sunlight, solar radiation, wind, natural daylight and thermal characteristics of the building skin. The aim of this paper is to present a specific case of energy efficient and environmental low-impact architecture and to examine the methodological productivity of architectural design assisted by bio-climatic studies in the lab.

Keywords: sustainable architecture, solar wind daylight simulation, Patagonia

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1. Methodology: Research Through Design

The modality of Research Through Design (RTD) requires the incorporation of analytical and experimental stages simultaneous and complementary to the design process. Whereas all design process necessary entail a certain degree of 'research', in this case the analytical side acquires a special relevancy and must be systematically applied and recorded. This allows, among other things, that the resulting project can be to a large extent rationally explained. On the other hand, given that the final result of the research is primarily a design project - unlike in other forms of scientific research - the research methods applied are always mediated by the intrinsic characteristics of the design process, including a high level of subjectivity in matters such as esthetic preferences of the designers-researchers.

In the case of the project here introduced, the systematic-research side, which complemented the design process, was guided by a quest to explore the environmental conditions of the location and the possible architectural responses that could be adopted in order to achieve bioclimatic comfort, high levels of energy efficiency and minimize the impact on the site. With this purpose, the research began by analyzing the climate at the site, reviewing specialized bibliography (e.g. de Schiller et al., 2003; Givoni, 1992) and developing the main design strategies. Along with the development of the design project, several simulations were performed for each proposal assessed. The aim of these tests was to contribute with additional elements to assist the decision process inherent to the design practice. The studies included Wind, Solar Radiation, Natural Daylight and Thermal Characteristics of the Built Envelope simulations. The following section introduces the analysis of the climate along with the characteristics of the project and main ideas behind it. Bellow, a selection of the results of the studies and simulations is presented.

1.1. Climate

According to the Norm IRAM 11.603, the site location corresponds to the Bioclimatic Zone V 'Cold', Sub-zone 'South'. The climate data analyzed were obtained from the closest

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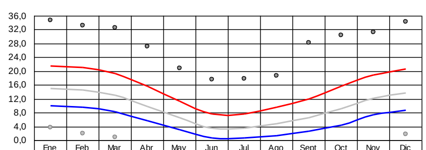
meteorological station with complete records, located in Puerto Deseado (Latitude: 47º44´S - Longitude: 65º55´W – Altitude: 80m).

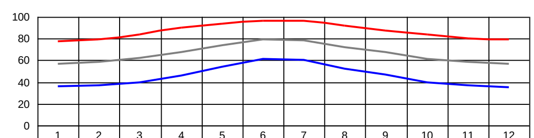
The medium temperature oscillates between approximately 15ºC in January and 3ºC in June and July. The maximum values are typically recorded in January, with 21.5ºC being the average maximum, and 34.6ºC the absolute maximum. The minimum values, in June and July, reach an average minimum of 0.6ºC and -10ºC of absolute minimum (Figure 1). According to the recorded data, and following the 'Degree Day' (DD) indicator, the energy demand on site is fairly elevated: 2551 DD, with 7 months of cold days, cold nights during the whole year, 5 months in which the thermal amplitude is higher than 10ºC, and 5 months with daytime heat.

The relative humidity, with average values between 57% and 79% (Figure 2), in this case does not represent a variable that could significantly affect the bioclimatic comfort zone. The humidity levels registered do not require specific ventilation strategies. The rainfall is low, thus it is difficult to grow vegetation without artificial irrigation. This characteristic of the climate limits the range of resources available to achieve protection from the strong Patagonian winds.



	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sept	Oct	Nov	Dic
Máxima	21,5	21,0	19,4	15,6	11,2	7,5	7,5	9,6	12,0	15,7	18,9	20,7
Media	14,9	14,5	13,0	9,9	6,5	3,5	3,5	4,8	6,5	9,2	12,2	13,8
Mínima	10,0	9,6	8,2	5,6	3,0	0,6	0,6	1,2	2,5	4,4	7,3	8,6
Min Abs	3,6	2,0	0,8	-3,4	-7,8	-10,0	-9,1	-7,0	-4,6	-2,4	-1,3	1,8
Max Abs	34,6	33,2	32,6	27,1	20,9	17,6	17,7	18,7	28,3	30,4	31,2	34,2

Figure 1 Temperature



	1	2	3	4	5	6	7	8	9	10	11	12
HR% max	77	79	84	90	94	97	96	92	88	83	80	79
HR% med	57	58	62	68	74	79	78	72	67	61	58	57
HR% min	36	37	40	46	54	61	61	53	46	39	37	35

Figure 2 Relative Humidity

The predominant wind comes from the West, with an annual frequency of 33% and a variation between 28% in summer and 40% in winter. The annual average speed is 28 km/hour, with a variation of the average value between 30 km/hour in summer and 24 km/hour in winter. The secondary wind comes from the South West with an annual frequency of 27% (28% in winter and 26% in summer) and average speeds similar to those of the West wind. In total, the sum of the winds from West and South West comprise a 60% of the records (Figure 3).

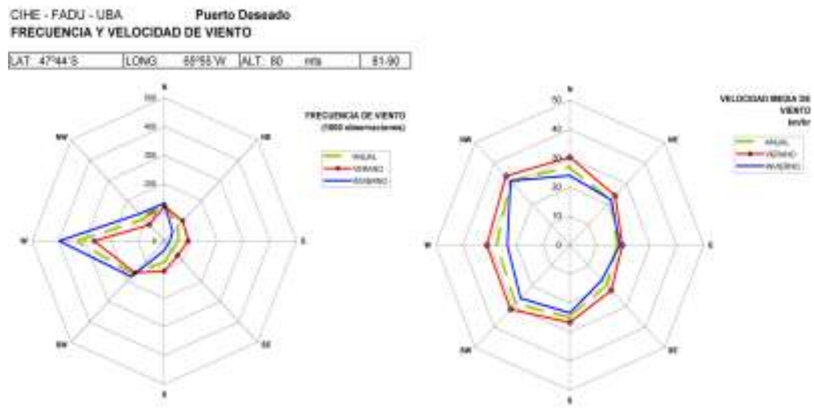


Figure 3 Predominant wind direction and speed

1.2. Design Strategies

The Interpretation Center project was a result of the creation of the Cañadón del Duraznillo Nature Reserve, located on the Atlantic coast of the Province of Santa Cruz, Argentina, 169km from Caleta Olivia and 120km from Puerto Deseado, with the aim of preserving the biodiversity of the sea-coastal environment associated with the Patagonian Steppe. The Interpretation Center program includes a multi-use space meant for exhibitions, conferences and film projections; an administrative office, a house for a park ranger and a room for guest researchers.

Apart from the studies and simulations above mentioned, another determining factor that conditioned the design process and selection of the materiality of the project was related with the availability of economic and technical resources. One of the preliminary stipulations was the determination of using a construction system of preassembled panels that could reduce the works on site to approximately a week. This decision was not only based on economic reasons – given the remoteness of the place, the transport of workers and materials typical in traditional constructions becomes an important item in the budget in this case – but also it was based on the aim of minimizing the construction works on site, and thus reduce the waste produced, energy use and disturbance of the tranquility of the site.

The preassembled panel system adopted, with balloon frame structure and exterior waved tin cladding, was selected based on the supply availability provided by local firms. The selection of this system is also consistent with thermal insulation requirements and the construction tradition of the Patagonian Atlantic Coast. In order to provide the mass with thermal inertia necessary to store heat in indoor spaces, a stone wall - the only masonry work on site – and a gabion wall were strategically located in the building. The orientation of the plan, disposition of the program and design of the envelop, respond to the solar geometry with the aim of maximizing the hours of solar gain, achieve adequate levels of daylight according to the use of each space and minimize that thermal loss. The compact morphology of the building was adopted as an answer to the cold climate. The program was set so the main spaces would face the (southern hemisphere) northern sun and that the thermal losses in the southern façade were minimal (Figure 4).

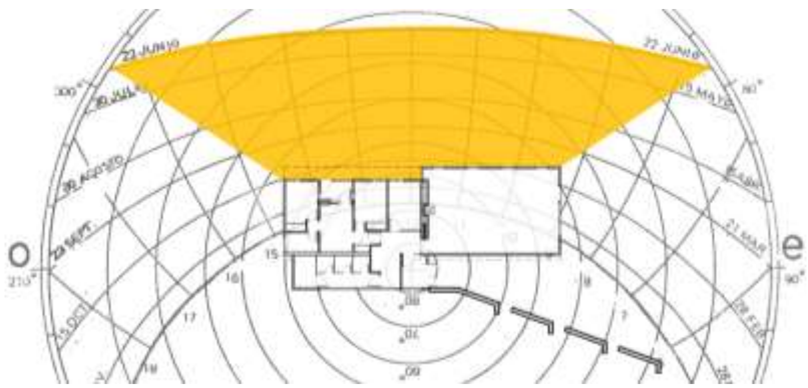


Figure 4 Orientation, morphology and disposition of the program according to the solar geometry

The conservatory space works as an independent access to the park ranger house and as a source of heat generation, which is transferred to the bedrooms and dining room through a stone wall with high thermal inertia. During summer months, the eaves of the roof provide solar protection to the glazed surface avoiding the effects of overheat (Figures 5 and 6). On the other hand, in summer warm days, the design of the openings allows the conservatory space to function wide open as a semi-covered chamber.

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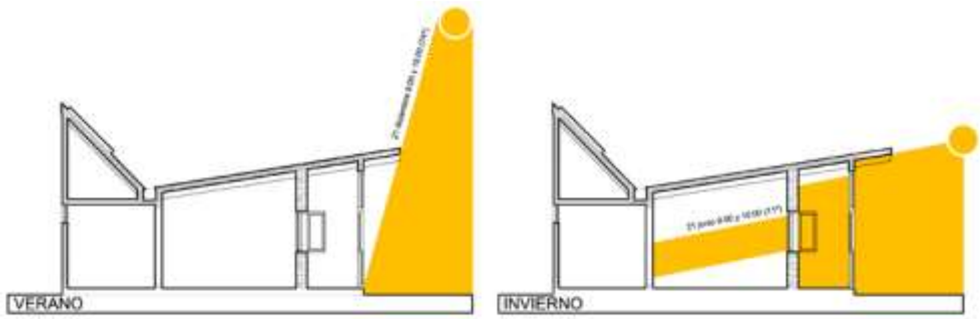


Figure 5 Solar gain an protection in the conservatory space

Summer solstice, 9:00 am | Equinoxes, 9:00 am | Winter solstice, 9:00 am

Summer solstice, 3:00 pm | Equinoxes, 3:00 pm | Winter solstice, 3:00 pm

Figure 6 Solar gain studies on the north elevation

The form and technical characteristics of the project also respond to the local wind conditions, with the aim of ensuring that the accesses to the building are well sheltered and avoid cold air infiltrations. Thus, the entrances to the building, through chambers, confer protection to the strong winds from the west and southwest (Figure 7). The roof of the sanitary volume, with solar flat collectors on the top, has an angle similar to the latitude of the site, 47ºS, to reach the highest annual average solar radiation gain. Besides, the slope of the main roof achieves the highest height on the north elevation - the one most exposed to solar radiation – and the lowest height on the southern side (Figure 8).

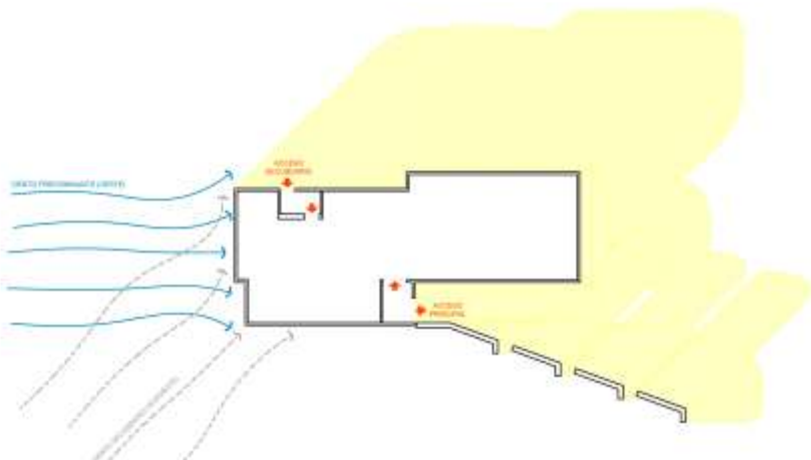


Figure 7 Access to the building and predominant winds

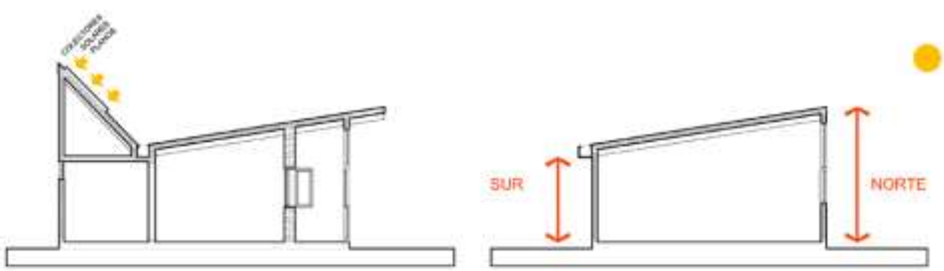


Figure 8 Roof slopes according to flat solar collectors and solar orientation

2. Results: Studies and Simulations

2.1. Wind

The main objective of the wind studies was to verify the design decisions taken in relation with the shelter of the access to the building and potential use of outdoor spaces. With this aim, simulations of speed variation and detection of still zones were performed in the Wind Tunnel. The speed values were registered with a hot-wire anemometer in 8 points selected (Table 1 and Figure 9) for both predominant wind directions (W and SW). As a result of these studies and a theoretical analysis of the model, the ‘wind shadows’ were estimated (Evans and de Schiller, 1994 [1988], p. 94) and the diagrams drawn (Figures 10 and 11)

Table 1 Points studied and speeds recorded for W and SW orientations at the Wind Tunnel

Nº	W (m/s)	SW (m/s)	Location
1	0.60	0.30	Access to the Conservatory Space, North
2	1.00	0.60	Outdoor space next to North elevation
3	0.30	0.40	Access to the main hall, East elevation
4	0.50	0.40	Start of the main pedestrian access, next to South elevation
5	0.50	0.50	Middle of main pedestrian access, next to South elevation
6	0.30	0.30	Main pedestrian access, next to South elevation
7	0.90	1.00	Outdoor space, next to South elevation
8	0.90	0.95	Outdoor space, next to West elevation
	1.00	0.95	Initial measurement
	1.00	1.00	Initial measurement

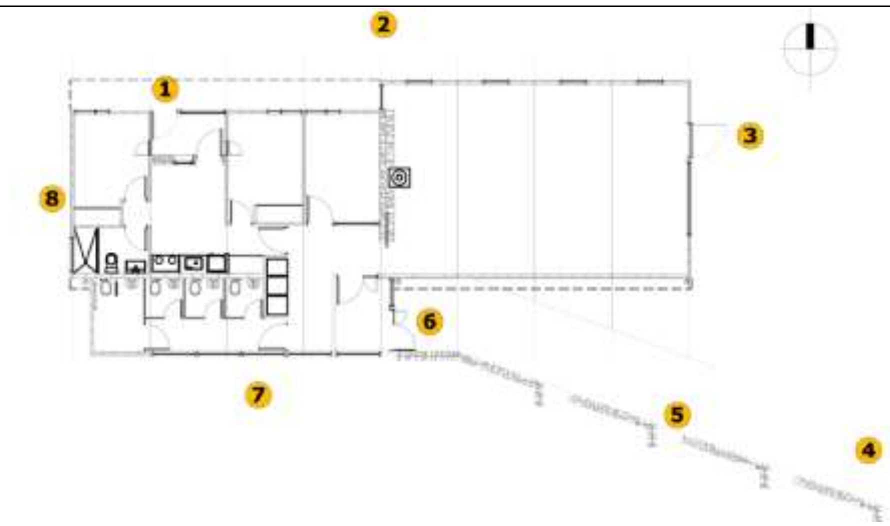


Figure 9 Location of the measured points

Figure 10 'Wind shadow' estimation (W)

Figure 11 Wind shadow' estimation (SW)

2.2. Solar Radiation

The solar radiation studies were performed with the aim of determining the thermal gain obtained during the cold months, and to verify the solar protection in the summer, especially in the conservatory space. Figure 12 presents the elevations exposed to solar radiation, with their respective glazed areas highlighted.

East: Façade area: 33.8m2 / Glazed area: 5.6m2 (16.6%)

West: Façade area: 33m2 / Glazed area: 1.71m2 (5.2%)

North: Façade area: 79.5m2 / Glazed area: 15.2m2 (19.1%)

Figure 12 East, West and North elevations with their glazed surfaces highlighted

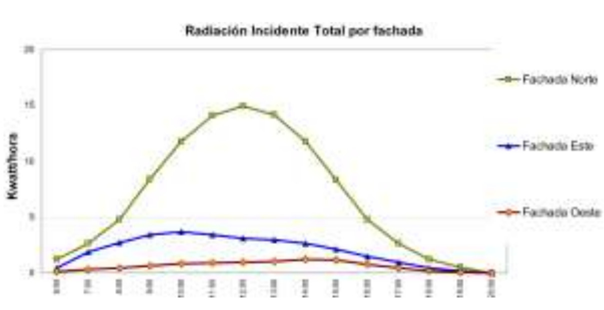
The elevation with the highest proportion of glazed area is that of the North, with a 19.1%. This is the elevation that receives less direct solar radiation in summer and more in winter (Table 2). The West face is the one with less glazed area (1,71m2), so thermal gains in the afternoons are avoided during summertime. Although the East and West elevations receive the same amount of radiation, in the case of the East face it was possible to increase its proportion of glazed area, given that this side collaborates with the early warming up of the building, without being able of overheating the indoor air.

Table 2 Direct solar radiation according to orientations and seasons

	East	North	West
Summer	808	608	808
Equinoxes	431	1047	431
Winter	244	1172	244

Figure 13 presents the Total Incoming Radiation values on the elevations examined. The North façade is the one that performs best from a thermal point of view. The levels of direct solar radiation penetration during winter are 3 times higher than those during summer. Direct solar gain will collaborate with the thermal conditioning of the building, decreasing the energy demand. The East elevation will help warming up the building catching the first solar rays of the day. The West façade, for only having 1.7m2 of windows, does not constitute a potential problem in summer. The disposition of windows and the eaves of the roof allow a similar amount of solar radiation penetration throughout the year. The cold climate of the site requires solar protection only during summer. The openings were design to provide shade and reduce the penetration of solar radiation only for this season. The practicable windows allow the access of breeze that could refresh the indoor spaces, especially in the exhibition space, were the opening facing East, North and West allow a fine circulation of air.

When outdoor temperature is low the conservatory captures more direct radiation, with a maximum performance in winter. The indirect solar radiation, diffuse and reflected, works inversely: it is higher in summer and lower in winter. For this reason, the lower openings in the conservatory, a sash window and a door, can be opened. During the days with maximum temperatures in summer the conservatory can function as a semi-covered ventilated space (Figure 14).



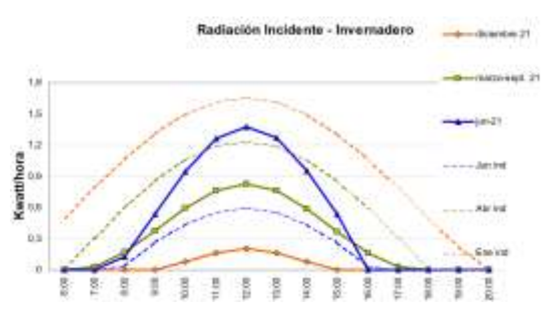


Figure 13 Total radiation gain by elevation

Figure 14 through the conservatory space

2.3. Natural Daylight

With the aim of assessing the levels and distribution of the Daylight Factor (DF) inside the main space, and assuring that the quantity and quality of natural daylight available for exhibition and gathering was acceptable, a set of simulations with the software 'Radiance', developed by the Lawrence Berkeley Laboratory, were performed. Figure 15 shows the values and distribution of DF in one of the initial simulations with daylight entrance mainly through horizontal windows placed in the upper face of the north elevation (left), and the adopted model with vertical windows with a larger glazed area equidistant distributed in the plan (right).

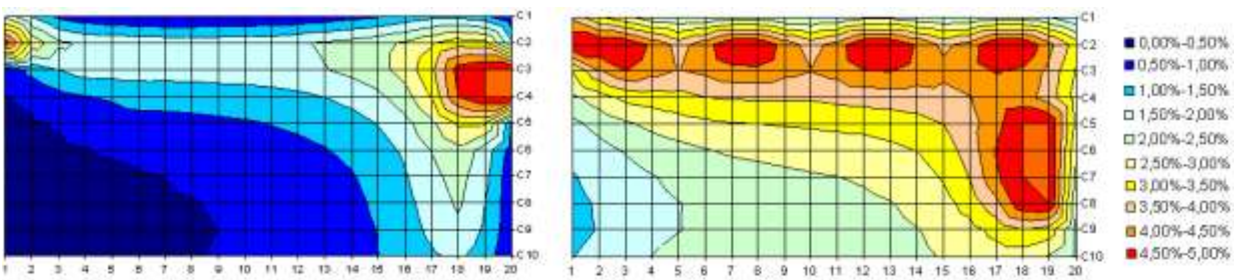


Figure 15 Daylight studies (Daylight Factor): initial simulations (left) and adpted model (right)

These simulations were not only developed to verify the final model, but also were useful to re-elaborate and adjust former models, which along with sunlight studies guided the design and position of the openings. In the process of deciding the final version, models with horizontal windows, with less and more glazed area and positioned with different distances, were assessed.

The adopted model achieves a good daylight distribution; more than 90% of the plan receives a Daylight Factor higher than 2%. The Norm IRAM AADL 20.03 considers 'acceptable' the DF values higher than 2%, represented in Figure 15 within the spectrum of light green to red colors.

2.4. Thermal Characteristics of the Envelope

The control of heat loss is a fundamental design factor in cold climates, as it is the case of this site in the Atlantic Patagonia. The incorporation of good levels of thermal insulation allows a reduction of heat demand, avoids the risk of superficial condensation and provides comfortable thermal conditions for users. In order to reduce thermal loss from heated spaces is necessary to consider the following factors:

To achieve a low thermal transmittance of walls, roofs and windows, in order to reduce the heat flow from indoor spaces to outdoor.

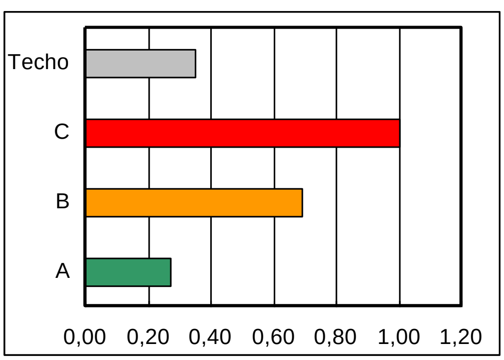
To reduce the total exterior area of the envelope through the adoption of a compact building form.

To locate the spaces with lower heat demand, such as the entrance hall and restrooms, as a buffer zone, protecting the heated spaces.

To control the ventilation rate, with double doors in the accesses, oriented to be sheltered from predominant winds.

With the aim of verifying the thermal insulation of the building, the levels of thermal transmittance of the design envelope were compared to those recommended by norms IRAM 11.605 for walls and roofs and IRAM 11.601 for windows. The parameters of the norms IRAM 11.900, with regard to the certification of energy efficiency, and IRAM 11.625 and 11.630 for superficial and interstitial condensation risk, were also examined.

The thermal transmittance of walls and roofs are Level B ‘good’, significantly lower to the minimum allowed for this category and closer to the Level A ‘optimal’ (Figure 16).



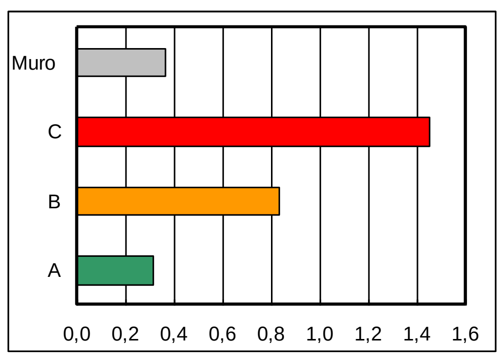


Figure 16 Comparison of the thermal transmittance values included in Norm IRAM 11.605, levels A, B and C, and thermal transmittance according to the design in the roof (left) and walls (right)

The heat loss in the roof during winter is 29% higher than a roof Level A, but also 50% lower than a roof that achieves the minimum requirements of one Level B. Heat loss in walls is 18%

higher than a wall Level A, but 56% lower than a wall labeled Level B with minimum requirements.

In order to assess the thermal behavior of the building, establish the conditions in which no heat is required and determine the overheating risk, a number of simulations of indoor temperature in winter, equinoxes and summer were performed for the bedroom and dining room spaces. The charts in Figure 17 indicate the time variation of outdoor and indoor temperature during a period of 24 hours. The simulations use meteorological data of temperature in a typical, or warmer than the average, day, with data of the medium intensity of solar radiation.

The results show that a stable indoor temperature is kept with limited variations, despite the light construction and the variable solar gains. The thermal insulation levels are enough to keep a temperature raise of 4ºC in summers, 8ºC in October and 5ºC in winter. This difference is the result of the variation of the incidence of solar rays, with a solar penetration more favorable in October-November and March-April. In winter, when the intensity of the sun is lower and sunny days are fewer, there is a reduction in the advantage that can be taken from this renewable energy for heat.

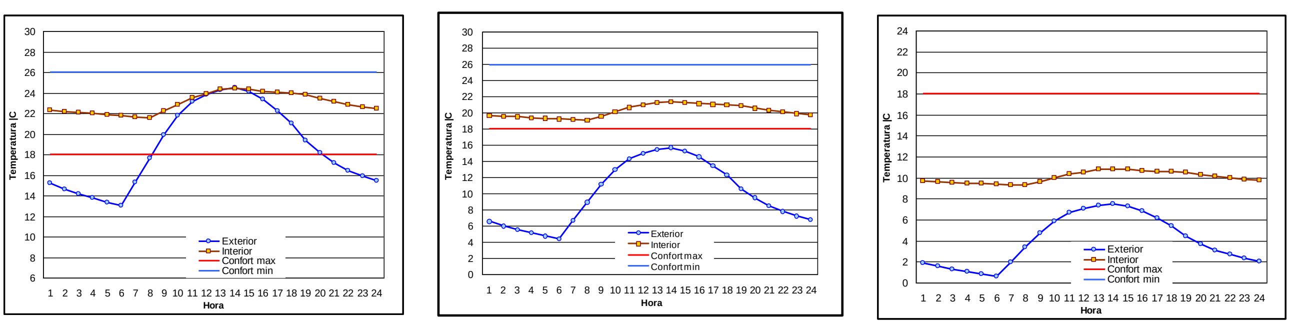


Figure 17 Indoor and outdoor temperature simulations in a day in January (left), October (center) and July (right)

3. Conclusions

The building form effectively protects the accesses from the predominant winds, especially those of the west, and does not provoke wind accelerations in any of the points studied in the

Wind Tunnel simulations, which were selected based on their strategic relevance in the project.

The solar radiation studies verify the adoption of the building form and the design of the openings with their largest areas facing the north. The performance of the conservatory is most favorable: the direct solar gains increase while outdoor temperature decreases, getting to the maximum gain during the winter solstice. On the other hand, the daylight simulations performed confirm the suitability of the design of the windows. Their vertical proportion and position in the center of each module, respecting the rhythm and spatial and constructive modulation, favors the light distribution, especially considering the potential inclusion of internal divisions with exhibition panels.

Finally, after the study of the thermal characteristics of the envelope in relation to the initial recommendations and IRAM norms, it was determined that that the thermal behavior of the envelope is reasonably energy efficient, with acceptable comfort levels without a need of heating during most of the year and with five months in which the energy demand for heating is fairly low. These values are achieved primarily with the building design and could be increased, so ideal values are reached, with a higher construction budget.
Thus, this case study is also useful to examine the scope and limits of design strategies to achieve energy efficiency in relation to materials and construction techniques adopted that are conditioned by budget restrictions and the availability of technology on site.

Acknowledgements

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